



CHAPTER VIII TRAFFIC CONTROL DEVICES

SECTION 8-01

HIGHWAY LIGHTING

8-01.1 DEFINITIONS.

AASHTO GUIDE. Latest edition of "An Informational Guide for Roadway Lighting."

ADAPTATION (TRANSITION) LIGHTING. Provisions for gradual or incremental changes in the intensity of illumination to allow the eye to adapt from light to dark conditions.

AVERAGE MAINTAINED ILLUMINANCE. The average level of horizontal illuminance on the roadway pavement when the output of the lamp and luminaire is diminished by the maintenance factors: expressed in average footcandles [lux] for the pavement area.

AVERAGE INITIAL ILLUMINATION (Intensity). The average footcandles [lux] level of horizontal illumination on the pavement area, at the time of installation, when lamps are new and luminaires are clean.

CANDELA. The unit of luminous intensity; one lumen per unit solid angle (steradian) (1 candela per square inch = 452 footlamberts).

COEFFICIENT OF UTILIZATION. The percentage of the lumens emitted by the lamp that is received on the surface of the pavement.

DISCERNMENT BY SURFACE DETAIL (DIRECT REFLECTANCE). Lighting which provides direct illumination of the side of the object toward the observer. The object is seen by variations in brightness or color over its own surface without general contrast with a background.

FOOTCANDLE. The illumination on a surface one square foot in area on which there is uniformly distributed a light flux of one lumen. One footcandle equal 10.76 lux.

FOOTLAMBERT. The unit of photometric brightness (luminance). It is equal to $1 / \pi$ candela per square foot, or the uniform luminance of a perfectly diffusing surface emitting or reflecting light at the rate of one lumen per square foot. One footlambert equals 3.426 candela per square meter.

I.E.S. Illuminating Engineering Society of North America. This organization develops and publishes standards for roadway lighting practices as well as other types of lighting.

LIGHTING UNIT. Assembly of lighting pole, bracket arm, and luminaire with lamp and ballast.

LUMEN. A unit of measure of the quantity of light. One lumen is the amount of light emitted in a unit. One candela (candle) emits a total of 12.57 lumens solid angle (steradian) by a uniform point source.

LUMINAIRE. A complete lighting device consisting of a light source together with its direct appurtenances such as globe, reflector, refractor, ballast, housing and such support as is integral with the housing.

LUMINAIRE MAINTENANCE FACTOR. An empirical depreciation factor of 70 percent to be applied to the calculated initial average footcandles [lux] to determine the value of average illumination at time of lowest output, and which represents the combined effects of reduced lamp lumen output and luminaire dirt accumulation.

LUX. The International System (SI) unit of illuminance. It is defined as the amount of light on a surface of one square meter all points of which are one meter from a uniform source of one candela.

SILHOUETTE DISCERNMENT. Lighting which provides a contrast between an object and its background so that it becomes readily recognizable to the motorist that the darker object is separate and different from its light background.

UNIFORMITY OF ILLUMINANCE. The ratio of the average footcandles [lux] of illumination on the pavement area to the footcandles [lux] at the point of minimum illuminance on the pavement. It is commonly called the uniformity ratio. A uniformity ratio of 3:1 means that the average footcandles [lux] value on the pavement is three times the footcandles [lux] value at the point of least illuminance on the pavement.

8-01.2 DEPARTMENT POLICY

8-01.2 (1) LIGHTING TO BE PROVIDED, OPERATED, AND MAINTAINED AT STATE EXPENSE

8-01.2 (1) (a) INTERCHANGES. Basic lighting along the major road at interchanges is provided if one or more of the following warrants are met: (1) If construction year ADT on the major road exceeds 25,000 for urban conditions, 20,000 for suburban conditions, or 10,000 for rural conditions, and the traffic on the crossroad exceeds 1500. (2) If the accident ratio of night to day exceeds 1.25 within the interchange area. (3) If the construction year ADT ramp traffic entering and leaving the major road within the interchange area exceeds 5,000 for urban conditions, 3,000 for suburban conditions, or 1,000 for rural conditions and the traffic on the crossroad exceeds 1,500. [Figures 8-01.1, 8-01.2 and 8-01.3](#) illustrate the typical location of luminaires for basic lighting at interchanges.

8-01.2 (1) (b) BASIC LIGHTING AT INTERSECTIONS INCLUDING RAMP TERMINALS AT CROSSROAD. Basic lighting at intersections is provided if any of the following warrants are met: (1) If the intersection is signalized. (2) If divisional islands are used (see [Subsection 4-05.3 \(2\)](#)). (3) If construction year ADT on the crossroad exceeds 15,000 for urban conditions. (4) If basic lighting along the freeway is provided. (5) If the accident ratio of night to day exceeds 1.25. (6) If poor sight distance exists. [Figure 8-01.4](#) illustrates the typical location of luminaires for basic lighting at channelized intersections.

8-01.2 (2) LIGHTING TO BE PROVIDED, OPERATED, AND MAINTAINED AT THE EXPENSE OF THE LOCAL POLITICAL SUBDIVISION

8-01.2 (2) (a) FREEWAYS

8-01.2 (2) (a) 1. BASIC LIGHTING. Basic lighting in accordance with commission standards and specifications may be provided at intersections or interchanges where desired by the local political subdivision.

8-01.2 (2) (a) 2. CONTINUOUS LIGHTING. Continuous lighting in accordance with Commission standards and specifications may be provided where desired by local political subdivisions. In this case, the commission will provide, at the time of construction, conduits and bases on structures and crossings under pavement if an agreement between the state and the political subdivision for lighting is made at the time. Continuous lighting may be provided through the interchange providing the crossroad is lighted for an acceptable distance away from the interchange.

8-01.2 (2) (a) 3. POLES, LUMINAIRES, AND WIRING. All lighting is to meet state standards for freeway lighting including steel or aluminum poles with breakaway features and underground wiring.

8-01.2 (2) (b) OTHER THAN FREEWAYS. Lighting on state highways, where desired by local political subdivisions, may be permitted provided such lighting will in no way detract from or reduce the effectiveness of lighting placed by the state or in any way interfere with the safe and orderly movement of traffic. All lighting is to meet state standards and the state retains full authority to exercise control in all matters relating to design and operation of such installations. A permit may be granted to the local political subdivision to install lighting at public road intersections or along the highway. [Figures 8-01.6 and 8-01.7](#) illustrate typical lighting plans by permit. These figures are to be used only as a guide for the district to issue permits to local political subdivisions who request permission to install lighting facilities on existing highways and are not for design purposes. In cases where an agreement between the state and the political subdivision for

lighting is in effect at the time of construction of the highway, the state will provide, at the time of construction, conduits and bases on structures and conduits for crossings under pavements. It is the district's responsibility to advise General Headquarters Bridge of the need for providing conduit systems and bases for lighting poles on bridges.

Extensions or additions to lighting facilities installed by the state must be made using steel or aluminum poles with breakaway features. If the state installation has underground wiring, then additions within the limits of the installation must be made using underground wiring.

Lighting facilities installed by a local political subdivision on expressways and expressway ramps must incorporate steel or aluminum poles with breakaway features and underground wiring within the clear zone and be located a minimum of 2 feet [0.6 m] behind the face of the curb or shoulder point. Wood poles or poles without breakaway features are acceptable only when located beyond the distance required by the clear zone guidelines. This requirement also applies to lighting installed within the limits of basic lighting installed or proposed by the state.

- 8-01.2 (3) LIGHTING TO BE ADJUSTED AT STATE EXPENSE AND OPERATED AND MAINTAINED AT THE EXPENSE OF THE LOCAL POLITICAL SUBDIVISION.** The state bears the cost for the first adjustment of existing lighting owned or leased by the local political subdivision, on roads that are being widened or reconstructed that were lighted prior to taking the road into the state highway system. Thereafter, the local political subdivision will be required to bear the adjustment costs.

The state will also bear the cost for (1) the replacement or adjustment of existing lighting owned or leased by the local political subdivision on streets (non-state owned) that are modified by MoDOT construction; (2) lighting on an outer roadway if the outer roadway is a readjustment or replacement of an existing road which is lighted; or (3) lighting for traffic circulation on lighted streets which are dead ended by highway construction.

The lighting system is designed to the state's current standards. The operation and maintenance is at the expense of the local political subdivision. The local political subdivision must indemnify and save the state harmless from any claims of the owner of the lights which are being leased to the local political subdivision.

Lighting that is on state right of way by permit will be relocated and upgraded to current design standards at the expense of the local political subdivision. In this way, lighting on state right of way by permit is treated similar to utilities since the local political subdivision constructed the lighting on land belonging to the state. It is the district's responsibility to notify the local political subdivision of the required adjustment. The lighting negotiations should be handled similar to other utility adjustments on the project.

- 8-01.2 (4) STATE PARTICIPATION IN CONTINUOUS FREEWAY LIGHTING BY A LOCAL POLITICAL SUBDIVISION.** When continuous lighting, including basic lighting of the ramp terminals at the crossroad, is provided and one or more of the following warrants are satisfied, the state will assume the then applicable federal-aid ratio of the installation costs, with the local political subdivision assuming the remainder of the installation cost and all costs of operation and maintenance.

- 8-01.2 (4) (a) CASE A WARRANT.** Where, for a length of two or more miles [three or more kilometers], the freeway passes through a substantially developed suburban or urban area in which one or more of the following conditions exist: (a) Local traffic operates on a reasonably complete street grid having some form of street light, parts of which are visible from the freeway; (b) The freeway passes through a series of developments such as residential, commercial, industrial and civic area, colleges, parks, terminals, etc., which include roads, streets, parking areas, yards, etc., that are lighted; (c) Separated cross streets, both with and without connecting ramps occur with an average spacing of $\frac{1}{2}$ mile [0.8 km] or less, some of which are lighted as part of the local street system; (d) The freeway cross section elements are substantially reduced below desirable standards.

- 8-01.2 (4) (b) CASE B WARRANT.** Three or more successive interchanges exist located with an average spacing of $1\frac{1}{2}$ miles [2 km] or less, and adjacent areas outside the right of way are substantially urban in character.

8-01.2 (4) (c) CASE C WARRANT. In and near cities where the construction year ADT is 30,000 or more.

8-01.2 (5) FUTURE LIGHTING. If future lighting is anticipated but is not initially warranted, rigid conduit is provided under pavement and shoulders and conduit systems and bases for lighting poles are provided on bridges. It is the district's responsibility to advise General Headquarters Bridge of the need to provide the conduit systems and bases for lighting poles on bridges.

8-01.3 PROGRAMMING. Lighting to be installed with the general construction of a highway is not incidental to such construction and is listed in the "Type of Improvement" on the construction program in accordance with [Section 1-02](#). It is eliminated at the design stage if not warranted for installation at the time of completion of the general construction. Lighting on an existing intersection, interchange or roadway is programmed approximately three years prior to installation.

8-01.4 DESIGN

8-01.4 (1) AUTHORIZATION. Lighting design is authorized by the district when justified in accordance with the department policy as stated in [Subsection 8-01.2](#). Warrant forms and traffic data are documented by the district for each installation, that is for each interchange and each intersection where basic lighting is proposed, or for each project if continuous lighting is proposed.

The following guidelines are for state installed, operated, and maintained lighting facilities. Lighting facilities installed by permit from the GHQ Traffic may incorporate variations due to selection of equipment and location.

8-01.4 (1) (a) WARRANT FORM D-21 (FIGURE 8-01.8). Form D-21 should be completed for each installation. The D-21 can be found in the Design forms on the computer system. On this form, the Sections 1. CONDITIONS, 2. PROPOSED DESIGN, and 3. COSTS are largely based on department policy as outlined in [Subsection 8-01.2](#). When the CONDITIONS justify the PROPOSED DESIGN, further warrants are not required. Section 4. ADT AT TIME OF COMPLETION is applicable only to freeways and interchanges. The construction year ADT is obtained from the Office of Transportation Program Management. When continuous freeway lighting is proposed only the volume on the freeway through-lanes is shown, since continuous freeway lighting includes interchanges. The volumes on crossroad through-traffic lanes and of ramp traffic are also shown when interchange lighting alone is proposed. The volume for through-traffic lanes on a freeway or crossroad is the total volume proceeding straight through an interchange in opposite directions. One of these would be N to S plus S to N, the other E to W plus W to E. The sum of all other movements would be the ramp traffic entering and leaving the freeway.

8-01.4 (1) (b) FORM HP-770. The current ADT, the construction year ADT, the percent truck traffic, and the peak hour traffic are included on Form HP-770 ([Figure 8-02.6](#)). This information is obtained from the Office of Transportation Program Management on request. Estimates of traffic for short sections of a roadway facility are unreliable, as they are not correct when additional sections are added. Therefore, estimates are based on a completed facility.

8-01.4 (2) LIGHT SOURCE AND INTENSITY

8-01.4 (2) (a) HIGH PRESSURE SODIUM LAMPS. H.P.S. lamps are used for fixed source lighting of roadways and underpasses. 150-watt lamps are rated at 16,000 lumens, 250-watt lamps are rated at 27,500 lumens, and 400-watt lamps are rated at 50,000 lumens.

8-01.4 (2) (b) AVERAGE MAINTAINED INTENSITY. The average maintained intensity is the average level of horizontal illuminance on the roadway pavement when the output of the lamp and luminaire is diminished by the maintenance factor.

Continuous lighting installations along freeways, urban arterials, expressways and ramp connections thereto must provide an average maintained intensity of not less than 0.6 fc [6.5 lux] and a minimum intensity of not less than 0.2 fc [2.2 lux]. Continuous lighting installations on existing roadways, not

including freeways, urban arterials, expressways or ramp connections thereto, must provide an average maintained intensity of not less than 0.4 fc [4.3 lux] and a minimum intensity of not less than 0.2 fc [2.2 lux].

Basic lighting at intersections, including ramp terminals at crossroads, should provide an average maintained intensity of not less than 0.6 fc [6.5 lux] and a minimum intensity of not less than 0.2 fc [2.2 lux] within the limits of the intersection.

The approach noses of all divisional islands and channelizing islands with non-mountable curbs should be lit to a minimum intensity of 0.2 fc [2.2 lux] on the vertical face of the island. [Figure 8-01.18](#) shows the luminaire configuration and range of locations for typical island noses.

[Figures 8-01.4, 8-01.5 and 8-01.6](#) show lighting configurations for various types of intersections. [Figures 8-01.19 and 8-01.20](#) show the limits for various mounting heights and luminaire sizes for direct reflectance and silhouette discernment lighting. Proper lighting of island noses may also dictate mounting height and luminaire size in an intersection ([Figure 8-01.18](#)). Mixing silhouette discernment and direct reflectance lighting is not recommended. If an intersection contains one or more divisional islands or channelizing islands with non-mountable curbs, all luminaires should be located for direct reflectance lighting.

Basic lighting at interchanges provides an average maintained intensity of approximately 0.6 fc [6.5 lux] or higher in the areas lit. Examples of interchange lighting are shown in [Figures 8-01.1, 8-01.2 and 8-01.3](#). The areas that are lit in an interchange are areas of potential vehicle conflict including exit gore areas, the ends of acceleration lanes, ramp merges, ramp diverges, weaving areas, ramp terminal intersections, etc. [Figure 8-01.21](#) shows luminaire locations for typical on and off ramps to maintain required intensities.

Where high mast lighting is used at complex interchanges, the lighting provides an average maintained intensity of not less than 0.6 fc [6.5 lux] and a minimum intensity of not less than 0.2 fc [2.2 lux] on all paved driving surfaces within the interchange. The areas of potential vehicle conflict as described above are lit to a maintained intensity of 0.6 fc [6.5 lux] or higher.

The figures in this manual show configurations for many typical situations. For unusual geometrics or lighting conditions, General Headquarters Design may be contacted for assistance in analyzing illumination levels.

- 8-01.4 (2) (c) UNIFORMITY.** The uniformity ratio is the ratio of average footcandle [lux] of illuminance on the pavement area to the footcandle [lux] at the point of minimum illuminance on the pavement. Continuous lighting must provide a uniformity ratio of 4:1 or better for 45 ft. [13.5 m] mounting heights and 6:1 or better for 30 ft. [9 m] mounting heights. Spacing of luminaires based on this criteria is as set out in [Subsection 8-01.6](#).
- 8-01.4 (2) (d) ADAPTATION (TRANSITION) LIGHTING.** Adaptation lighting attempts to reduce the rapid and extreme changes in levels of illuminance which occur when entering or leaving a continuously lighted section of roadway. Adaptation lighting is also used to adapt the driver to continuous interchange lighting before important decision points. The value of adaptation lighting is debatable since it is difficult to attain a gradual uniform change. Adaptation lighting is recommended for the extremities of a continuous lighted section of roadway that is a mile [1.5 km] or more in length or complex interchanges that are continuously lit. The transition effect is attained by decreasing the intensity of the last few luminaires, rather than by using increased spacing. Typically, the transition section is 15 seconds in length and the average intensity is approximately 50 percent of the intensity in the continuously lit section.
- 8-01.4 (2) (e) UNDERPASS LIGHTING.** Underpasses over 75 ft. [22.5 m] long, measured at right angles to the structure, are lighted with underpass luminaires when necessary to maintain the continuity of existing or proposed lighting. If roadway lighting units positioned near each portal provide sufficient light to penetrate the underpass and maintain the same intensity of illumination or uniformity ratio as is used on the approach roadways, the underpass luminaires are not used.

8-01.4 (2) (f) HIGH MAST LIGHTING. High mast lighting is the lighting of a large area by means of a group of luminaires that are designed to be mounted in a fixed orientation at the top of a high mast (generally 80 ft. [25 m] or higher). High mast lighting is used principally at complex interchanges. High mast lighting must be authorized by the district. The request for conceptual approval for high mast lighting should be included with the lighting warrants. Data supporting the selection of pole height, pole location and type of luminaires should be included with the preliminary lighting plan. Where high mast lighting is used at complex interchanges, adaptation lighting is recommended for each section where vehicles enter and leave the interchange.

8-01.4 (3) MOUNTING HEIGHTS. 150-watt lamps are mounted 30 ft. [9 m] above the pavement. 250-watt and 400-watt lamps are mounted 45 ft. [13.5 m] above the pavement. Requests for mounting heights other than 30 or 45 ft. [9 or 13.5 m] should be coordinated with General Headquarters Design.

8-01.4 (4) LOCATION OF LUMINAIRES AND POLES FOR 30 ft. [9 m] MOUNTING HEIGHT. Luminaires are mounted 30 ft. [9 m] above the edge of traveled way and within 3 ft. [0.9 m] of the edge of traveled way for greatest utilization of available light. Lighting poles have a 28 ft. [8.5 m] shaft length and an 18 in. [455 mm] bracket rise. The 30 ft. [9 m] mounting height of the slip-fitter above the edge of traveled way is attained by means of adjusting the bracket mounting plates on the shaft.

Type AT (ground mounted) poles have breakaway features. Shafts do not require handholes, as splices are performed in the transformer base. Poles behind guardrail, installed for purposes other than protection of lighting poles, are installed in accordance with [Standard Plan 606.00](#).

Type B (bridge mounted) poles on bridge safety barrier curbs of 2'-8" [815 mm] height will result in a 30 ft. [9 m] mounting height above edge of traveled way.

Poles mounted on structures other than bridge safety barrier curbs, such as retaining walls, will require special lengths.

8-01.4 (5) LOCATION OF LUMINAIRES AND POLES FOR 45 ft. [13.5 m] MOUNTING HEIGHT. Luminaires are mounted 45 ft. [13.5 m] above the edge of traveled way and no further than 5 ft. [1.5 m] horizontal from the edge of traveled way unless clear zone requirements dictate otherwise. If the clear zone exists, the following should be followed:

- If the clear zone is less than or equal to 20 ft. [6.0 m], the pole should be located such that the luminaire is a maximum of 5 ft. [1.5 m] from the edge of traveled way

20 ft. [6.0 m] maximum - 15 ft. [4.5 m] bracket arm = 5 ft. [1.5 m] maximum setback

- If the clear zone is greater than 20 ft. [6.0 m] and less than or equal to 30 ft. [9.0 m], the pole should be located such that the luminaire is a maximum of 15 ft. [4.5 m] from the edge of traveled way

30 ft. [9.0 m] maximum - 15 ft. [4.5 m] bracket arm = 15 ft. [4.5 m] maximum setback

Where right of way is sufficient, lighting poles located on the outside of the roadway should be placed outside the clear zone, but no further than 30 ft. [9 m] from the edge of traveled way in order to maintain an effective utilization of the light source. Poles should be located at a uniform distance from the roadway. Lighting poles located on the outside of ramps are to be placed a maximum of 20 ft. [6.0 m] from the edge of the ramp driving lane. See [Figure 8-01.21](#) for luminaire locations at on and off ramp areas. Lighting poles located adjacent to auxiliary lanes are placed no further than 30 ft. [9 m] from the nearest edge of the through lane. Lighting poles have a bracket rise of 5'-6" [1.7 m]. The 45 ft. [13.5 m] mounting height of the slip-fitter above the edge of traveled way is attained by means of adjusting the bracket mounting plates on the shaft.

Type AT (ground mounted) poles have breakaway features. Shafts do not require handholes, as splices are performed in the transformer base. Poles behind guardrail, installed for purposes other than protection of lighting poles, are installed in accordance with [Standard Plan 606.00](#). Shaft lengths are determined from the cross-section at each pole location, for pole designs 1 through 5 as shown on the plans.

Type B (bridge mounted) poles on bridge safety barrier curbs of 2'-8" [815 mm] height will result in a 45 ft. [13.5 m] mounting height above edge of traveled way.

Type MB (median barrier mounted) poles on median barrier of 2'-8" [815 mm] height will result in a 45 ft. [13.5 m] mounting height above edge of traveled way.

Poles mounted on structures other than bridge safety barrier curbs and concrete median barriers, such as retaining walls, require special lengths.

- 8-01.4 (6) LIGHTING POLES LOCATED IN MEDIAN.** Poles are not located in the median of a divided highway, under normal conditions, for overall pavement and median widths up to 100 ft. [30 m], unless it becomes economically impractical to light the roadway from the outside shoulders. The following instructions apply to trafficways in urban areas which cannot be economically lighted from the outside because of the overall width of multi-lane pavement to be lighted, and do not apply to divided roadways with two 24 or 36 ft. [7.2 or 10.8 m] pavements with a wide median where each pavement may be lighted individually from poles located on the outside shoulders.

Where lighting poles are located within a barrier median, the total median width is at least 8 ft. [2.4 m], and the width between barrier curbs at least 4 ft. [1.2 m]. The width between barrier curbs may be less than 4 ft. [1.2 m] if the total width of median is more than 8 ft. [2.4 m].

A width of 12 ft. [3.6 m] for a mountable median is the minimum width for location of lighting poles.

If the guardrail and lighting poles are placed in a median, the lighting pole is located at approximately the midpoint between guardrail posts with the handhole in line with the guardrail. To utilize standard guardrail sections, the lighting pole spacing is in multiples of 6'-3" [1905 mm]. This spacing is measured along the centerline of the guardrail and not along the survey baseline unless the two coincide.

The actual spacing of the light poles should be the possible spacing nearest to the calculated theoretical spacing required to obtain the average maintained intensity of light.

Only in exceptional cases can lighting be entirely from poles located in the median, such as depressed roadway with retaining walls or on or behind concrete median barriers because there is better utilization of effective lumens from lamps located on the outside of wide pavements. For example, when a 20,000 lumen luminaire is located above the median edge of a six-lane highway with a 16 ft. [4.8 m] median, and a mounting height of 30 ft. [9 m], 40 percent is utilized. Where the same conditions exists for an installation over the outside edge, 58 percent is utilized. The maximum utilization is 60 percent. Good results are obtained by outside-inside alternating locations with twin bracket arms on the median poles. 150-watt underpass luminaires are sometimes mounted on the retaining walls of a depressed roadway.

In Summation: (1) Outside lighting is preferred where possible; (2) Alternate outside poles and median poles may be used for traffic ways with more than six lanes each direction provided the median design meets requirements; (3) Depressed roadways with retaining walls may be lighted entirely from median poles, with the same requirements for median design, or from underpass luminaires mounted on the walls.

- 8-01.4 (7) SIGNALIZED INTERSECTIONS.** Lighting shall be provided at all signalized intersections. All quadrants of the intersection should be illuminated whether or not there are islands on all approaches. Lighting at signalized intersections should provide an average maintained intensity as specified in [Subsection 8-01.4\(2\)\(b\)](#). If the intersection has raised channelizing islands or divisional islands, the intersection should be illuminated by direct reflectance (see [Figure 8-01.5](#)). The luminaire should be located in front of the nose of any island in accordance with [Figure 8-01.18](#). For those approaches without raised islands, the luminaire should be located as if an island existed on that approach. Direct reflectance and signal pole lighting should not be mixed.

At signalized ramp terminals where basic lighting along the freeway is planned or in place, lighting with separate light poles and conduit systems is recommended.

If the intersection does not have raised islands, the luminaires may be placed on the signal poles to provide silhouette discernment lighting (see [Figure 8-01.5](#)). Each quadrant of the intersection should be illuminated. The luminaires should be installed directly over the mast arms or cable spans to provide the proper silhouette effect. If the intersection is located within the limits of continuous lighting meeting intensity requirements, the signal pole lighting is not required.

Lighting control for 120 volt signal pole lighting or separate pole lighting is shown on [Standard Plan 902.15](#). If the capacity of this control box is exceeded or if the lighting is part of a larger system, then a 240 volt or 480 volt base-mounted control station is used. Where separate light poles and 240 and 480 volt lighting circuits are used at signalized intersections, the wiring, conduit, pull boxes and lighting control station should be separated from the signal equipment. It is not desirable to have higher voltage lighting wiring mixed with the 120 volt signal control wiring. Signal and lighting controllers can share a power supply, but separate meters and disconnect switches will be needed (see standard plans).

- 8-01.4 (8) CONTROL STATION AND POWER SUPPLY.** Control stations and power supplies consist of all equipment and materials necessary for the distribution of secondary electrical power. Control station design details are shown on the standard plans or approved special sheets. Secondary voltage should be provided by the utility, with any utility equipment substation located off of highway right of way.

A letter is required from the utility stating that they will provide secondary voltage to the necessary control stations. A copy of this letter is to be forwarded to General Headquarters Design.

Two types of lighting control systems are available for use as follows. If other types of control station designs are desired, they should be submitted to General Headquarters Design for approval.

- 8-01.4 (8) (a) 240 VOLT AND 480 VOLT FOUR CIRCUIT LIGHTING CONTROL STATIONS.** These control stations are base-mounted as shown on [Standard Plan 901.30](#). These control stations also require a Type 1 or Type 2 power supply as shown on [Standard Plan 901.80](#). These power supplies can also supply power for signal controllers.

These control stations are intended to be used with interchange lighting, continuous lighting and tower lighting systems. These control stations are also used with intersection lighting where the capabilities of the 120 volt control box described below are exceeded. Lighting and signal conduit systems are separate with 240 or 480 volt lighting systems. For installations requiring different voltages for lighting and signal applications, either two preformed pull boxes, or one double concrete pull box, Type B shall be used. Contractors may use the double concrete pull box, Type B in lieu of two preformed pull boxes.

- 8-01.4 (8) (b) POWER SUPPLY WITH 120 VOLT LIGHTING CONTROL BOX.** This system incorporates a small lighting control box on a Type 1 or Type 2 power supply assembly as shown on [Standard Plan 902.15](#). With this system, lighting wiring can be incorporated into signal conduit systems.

This system is intended to be used for lighting at both signalized and unsignalized intersections. This system can be used at intersections with signal pole lighting or separate lighting poles under the following conditions:

- Lighting cable sizes are no greater than #8 AWG [10 mm²].
- No more than 6 – 150-watt luminaires, 6 – 250-watt luminaires, or 4 – 400-watt luminaires.
- No more than six 2c - #12 [2c - 4 mm²] cables or eight 1c - #8 [1c - 10 mm²] cables.

If any of these conditions are exceeded, then the 240 volt, 4-circuit control station should be used.

8-01.4 (9) CIRCUITING

- 8-01.4 (9) (a) SYSTEM VOLTAGE.** The department standard is either 480 volt or 240 volt multiple circuit systems. The following guidelines should be used to determine the system voltage:

8-01.4 (9) (a) 1. 240 VOLT SYSTEMS

- Basic Intersection Lighting (signal post systems are 120 volt).
- Basic Interchange Lighting at Diamond Interchanges.

8-01.4 (9) (a) 2. 480 VOLT SYSTEMS

- Basic Interchange Lighting at Complex Interchanges.
- Continuous Lighting of Interchanges or Roadways.
- High Mast Lighting.

Lighting system voltages cannot be mixed in a single interchange or system. Long cable runs may require an increase from 240 volts to 480 volts (see [Subsection 8-01.7 \(1\)](#)). Both 240 and 480 volt secondary service is generally available at most locations. The availability of the desired system voltage should be verified with the local utility company.

8-01.4 (9) (b) EQUIPMENT. If a municipality will operate and maintain lighting in accordance with our policy, other types of circuits may be used at the request of the municipality. State-owned equipment is mounted as shown on standard plans or approved special drawings. Utility-owned equipment is mounted in accordance with practices of the utility company.

8-01.4 (9) (c) CONDUIT AND CABLE. Circuiting from control station to lights should follow the shortest possible route using current design standards. All circuits are underground, using cable-conduit with single conductor cables of the proper size so that voltage drop will not exceed five percent of the rated voltage. #8 AWG [10 mm²] cable is the minimum size to be used. All rigid conduit carrying cable-conduit under pavement and shoulder should be 3 in. [75 mm] minimum. Rigid conduit carrying cable-conduit located elsewhere should be 2 in. [50 mm] minimum. The amount of cable-conduit under pavement and shoulders should be kept to a minimum. Where practical, cable-conduit runs parallel to the roadway should be installed outside the shoulder.

2 in. [50 mm] or larger rigid conduit is used to carry lighting cables on structures or in median barriers. Design of conduit systems on structures should be coordinated with the General Headquarters Bridge. Where conditions require most of a system to be under pavement and shoulders or in median barriers or structures, the entire cable system should be installed in rigid conduit.

8-01.4 (10) PULL BOXES AND CABLE SPLICING. Cable splicing should be kept to a minimum and is only permissible in the base of a lighting pole, in a pull box or in a transformer base. Cable splicing in all poles is accomplished with a premolded fused splice. Cables should be continuous and unspliced between the control station, pull boxes and light poles.

If the distance between the control station, pull boxes and light poles is greater than 500 ft. [150 m] with cable-conduit or greater than 200 ft. [60 m] with rigid conduit, a pull box or junction box is to be provided to facilitate cable pulling. A pull box is installed on each end of any pavement crossing unless the pavement crossing ends in a light pole. See [Subsection 8-02.12](#) for information on pull boxes. The quantity and type of pull boxes are specified on the 2B sheets.

Two pairs of cables may be spliced into one light pole. Pole and bracket cable is to be used from the base of the pole to the luminaire. Pole and bracket cable consists of two #10 AWG [6 mm²] single-conductor cables. Where three pairs of cable are spliced (three-way splices) a pull box is recommended. Three-way splices should be avoided as much as possible. It is preferable to use an additional branch circuit from the control station, especially if the three-way splice is close to the control station. No more than three pairs of cables are spliced.

8-01.4 (11) POLES, BRACKET ARMS AND FOUNDATIONS. Lighting poles may be either steel or aluminum. The type may either be specified on the plans or left to the option of the contractor. The type of pole, as designated

on the plans, shows the mounting height of the luminaire above the edge of traveled way, not the actual length of pole. The proper length of pole and the method of attaining the mounting height of the luminaire above the edge of traveled way is described in [Subsections 8-01.4\(4\) and 8-01.4\(5\)](#).

Bracket arms are available in 4, 6, 8, 10, 12 and 15 ft. lengths for 30 ft. mounting heights [1.2 m, 1.8 m, 2.4 m, 3.0 m, 3.7 m and 4.6 m lengths for 9 m mounting height] and 6 and 15 ft. [1.8 and 4.6 m] bracket arms for 45 ft. [13.5 m] mounting heights. Only bracket arms of these lengths are used. The bracket arm designs are shown in the standard plans. Mast arms for mounting traffic detectors or traffic signals are not used on lighting poles as the poles are not designed to carry the extra load of the mast arm and unit. Pole foundations will be in accordance with the standard plans.

8-01.4 (12) LUMINAIRES

8-01.4 (12)(a) HIGH PRESSURE SODIUM (HPS) LUMINAIRES. HPS luminaires specified on the plans will have an internal ballast.

8-01.4 (12)(b) UNDERPASS LUMINAIRES. Underpass luminaires are 150-watt. HPS units with integral 240 volt or 480 volt ballasts for wall mounting outdoors.

8-01.4 (13) TRENCHING AND BACKFILLING. Trenching and backfilling will be classified as Type I, Type II or Type III as described in the standard specifications and shown on the plans. Great care should be exercised in classifying trenching and backfilling for bidding purposes, especially as to the possibility of encountering Type III. The limits of each type of trenching and backfilling are shown on the plans. Standard plans show the trench locations.

8-01.4 (14) SUMMARY. The following basic rules are applied to the geometric layouts for highway lighting at interchanges and intersections:

- Poles are not placed past the nose where a ramp leaves the thruway, nor within 35 to 50 ft. [10 to 15 m] of an overhead sign structure. Such points, as well as the noses of raised divisional islands and channelizing islands with non-mountable curbs, are lighted by direct reflectance, rather than by silhouette discernment, with a luminaire placed in front of the nose and to the right of an approaching vehicle as shown in the figures. For direct reflectance and silhouette discernment lighting at intersections it is important that luminaires be oriented properly as shown in the figures, otherwise the effectiveness and the distribution of the lighting is compromised.
- If a bridge is within a continuously lighted area, luminaires are required to the right of the approaching vehicle and in advance of the bridge end.
- If a bridge can be lighted to approximately the designed intensity in accordance with Rule 2, no luminaire is necessary on the structure. When necessary to locate lighting poles and luminaires on a bridge, it is advantageous to locate those units over bearing points or bents to lessen detrimental effects of vibration.
- Where continuous lighting is not being designed, the transition at the end of an acceleration lane or the beginning of a basic or auxiliary lane at an on ramp is lighted. One 250-watt luminaire mounted at 45 ft. [13.5 m] is installed at the end of the acceleration lane at the point where the lane is full lane width. Two 150-watt luminaires mounted at 30 ft. [9 m] can be substituted for this luminaire, but are not recommended. If used, one luminaire is installed at the point where the lane is full lane width and one at the point where the lane is about 5 ft. [1.5 m] wide but not less than 125 ft. [37.5 m] apart. See [Figure 8-01.21](#) for additional information.
- On sharp ramp curves that are to be continuously lighted, poles are required on the inside of the curve for safety reasons. Luminaires mounted on the inside of sharp curves are spaced 0.55 times the normal horizontal spacing, and those on the outside at 0.70 times the normal horizontal spacing.

8-01.5 PREPARATION OF PLANS

8-01.5 (1) METHODS. Lighting plans are prepared on tracings, or on good reproductions of the road plans created before road design details are shown, which would obscure the lighting design. The use of processed tracings is desirable.

8-01.5 (2) SCALE. Scales of 1" = 50' or 1" = 100' [1:500 or 1:1000] are preferred. However, if reproductions of the road plans are used, any scale is acceptable. A graphic scale is shown on each sheet.

8-01.5 (3) TOPOGRAPHY. Features affecting lighting design, such as entrances and approaches, pavement layout, existing pole lines, existing lighting fixtures, kind of lamps, and proposed lighting installation are shown on the plans by proper symbols.

Lighting symbols are shown on [Standard Plan 901.85](#). Widths of pavement, shoulders and traffic islands are shown. The beginning and end of pavement transitions and traffic islands are shown with stationing.

8-01.5 (4) CABLE AND CONDUIT. The actual proposed location of rigid conduit or cable-conduit is approximated on the plans. Straight line schematic diagrams are not acceptable. It should be possible to take off quantities of cable or cable-conduit by scaling. Cable-conduit is normally used for underground circuits that are not under pavement or shoulders or in concrete barrier or structures. Where the cable-conduit is located under paved areas and shoulders (including all shoulder types) it is encased in rigid conduit. Where the entire system or circuit is in rigid conduit, cable-conduit is not used. In this case, two single conductor cables plus a bare neutral (ground) of the required size are used for each circuit. Possible combinations of cables in cable-conduit are shown in [Table 8-01.8](#) of [Figure 8-01.11](#).

Where cable-conduit enters concrete barriers or structures, it enters a rigid conduit system. To minimize splices, cable-conduit is provided to the first light pole or junction box with a splice. Although the outer sheath of the cable-conduit is cut away from the cables where they enter the rigid conduit, cable-conduit is paid for to the first pole or junction box.

Conduit under pavement and shoulders for encasement of cable-conduit are sized according to [Table 8-01.9](#) of [Figure 8-01.11](#). Each end of a rigid conduit pavement crossing is terminated in a pull box or a light pole.

Rigid conduit for lighting is used in 2, 3, 4 and 5 in. [50, 75, 100 and 125 mm] sizes. Use [Table 8-01.1](#) as a guideline for minimum sizes of rigid conduit.

Rigid conduit should be of sufficient size for the amount of cable they carry. [Table 8-01.5](#) of [Figure 8-01.11](#) shows rigid conduit sizes based on wire size and quantity. Additional information on conduit sizing is found in [Subsection 8-02.13](#).

The district furnishes design data to General Headquarters Bridge for conduit, junction boxes and poles required on bridges.

TABLE 8-01.1
MINIMUM RIGID CONDUIT SIZES

| Application | Min. Size (in.) | Min. Size (mm) |
|---|--------------------|-------------------|
| In trench not under pavement | 2 | 50 |
| Power supply to control station | 2 | 50 |
| On structures, in median islands or median barriers | 2 | 50 |
| Under pavement or shoulders | 3 | 75 |
| In concrete bases | 3 | 75 |
| Field wiring between control station and first pull box | 4 | 100 |

8-01.5 (5) SUMMARY OF QUANTITIES AND ESTIMATE AND 2B SHEETS. All items of work for lighting are tabulated on the 2B sheets, either for lighting as a separate project or with roadway quantities.

8-01.5 (6) COMPUTATION OF QUANTITIES. The computations of quantities and increments for measurement are in accordance with the specifications and the tabulation of bid items in Chapter IV. The following rules apply to

the items listed:

The cable quantities are calculated by the "center to center" distance for the following:

- Control Station to Lighting Pole
- Lighting Pole to Lighting Pole
- Lighting Pole to Pull Box .

Rigid Conduit (In Trench) includes trenching and backfilling.

Additional cable quantities are added to provide slack and additional cable for future use. The additional length of each conductor cable and neutral wire, or of cable-conduit is computed as follows:

- On Power Supply = 8 ft. [2.4 m] per circuit.
- In Control Station = 8 ft. [2.4 m] per circuit.

Control Station to Lighting Pole, Lighting Pole to Lighting Pole or to Pull Box = 5% of the "center to center" distance for snaking.

- In lighting pole = 5 ft. [1.5 m] for each connection.
- In pullbox = 6 ft. [1.8 m] per run.

#10 AWG [6 mm²] single-conductor pole and bracket cable is computed as 2 x (mounting height + length of bracket arm).

The total plan quantity only, for each item, is shown on the "2B" sheets to the nearest 10 ft. [5.0 m].

8-01.5 (7) CONTROL STATIONS AND POWER SUPPLIES. Approval of the locations and details of equipment, including the cost to hookup, in writing, is obtained from the utility company furnishing power. Approved special drawings are required if standard plans cannot be used. Control stations on highway right of way should be state owned, rather than owned by the utility company.

Power supply assemblies are located about 2 to 4 ft. [600 to 1200 mm] inside the right-of-way line unless the utility pole providing service is located on the right of way. In that case, the power supply assembly should be located as close as possible to the utility pole. If required, the base-mounted control station can be located remotely from the power supply. The control station should be located as close as possible to the lighting system and at a location that is easily accessible to Traffic personnel. Clear zone requirements should also be used in determining control station location.

A rigid conduit run is installed from the power supply to the control station. Three single conductor power cables are required for the control station. The minimum size wire is #2 AWG [35 mm²]. Larger cables may be required due to voltage drop. [Subsection 8-01.7\(1\)](#) contains formulas for computing wire size and voltage drop.

In systems with base-mounted control stations, a pull box should be installed at the lighting control station. Rigid conduit containing the cables for branch circuits is installed from the control station to this pull box

8-01.5 (8) COORDINATION. Lighting plans are coordinated with the road, signal and signing plans to be sure there are no conflicts with other construction features. The designer needs to become acquainted with features such as existing overhead and underground utilities to avoid conflicts.

8-01.5 (9) FIELD CHECKS. Field checks of lighting plans are similar to the field checks required for other plans as outlined in Chapter IV.

8-01.5 (10) COORDINATION WITH GENERAL HEADQUARTERS DESIGN. A representative of General Headquarters Design is available on request of the district at any time for review of plans, field checks, etc.

8-01.5 (11) PRELIMINARY PLANS. Preliminary lighting layouts showing the location of all luminaires, tentative

locations of control stations, power supplies and cable routing are reviewed at the district level. After approval of the preliminary layout, the district furnishes design data to General Headquarters Bridge if conduit or poles are required on structures.

8-01.6 HIGH PRESSURE SODIUM LUMINAIRE PERFORMANCE AND COMPUTATION OF ROADWAY ILLUMINATION

- 8-01.6 (1) ISO-FOOTCANDLE DIAGRAM.** An iso-footcandle [iso-lux] diagram is a means of showing the illumination on a roadway surface from one or more luminaires. Such a diagram is a graphical representation of points of equal illumination connected by a continuous line. Footcandle [lux] values on a horizontal plane from a single unit with a 30 ft. [9 m] mounting height are shown on [Figures 8-01.12, 8-01.13, 8-01.14 and 8-01.15](#). These curves are for a luminaire mounting height of 30 ft. [9 m]. Correction factors as listed are used for other mounting heights. Each IES type of illumination has a different pattern, as shown on [Figure 8-01.17](#). The types of luminaires are: Type III medium distribution, semi-cutoff, with 150-watt clear lamp as shown on [Figure 8-01.13](#) is mounted at 30 ft. [9 m] and is mainly used for basic lighting; Type II medium distribution, semi-cutoff, with 250-watt clear lamp, as shown on [Figure 8-01.12](#) is mounted at 45 ft. [13.5 m] and is used for continuous lighting; Type III medium distribution, semi-cutoff, with 250-watt clear lamp, as shown on [Figure 8-01.14](#) is mounted at 45 ft. [13.5 m] and is used for continuous and basic lighting; the 400-watt Type III medium distribution, semi-cutoff, as shown on [Figure 8-01.15](#) is mounted at 45 ft. [13.5 m] and is used for continuous and basic lighting

Luminaires used are the internal ballast type where the type of distribution is determined by the socket position of the lamp. There are variations in the light pattern for different makes of luminaire. The diagrams shown are typical and can be used for design purposes. From these diagrams the initial level of illumination on the pavement from one or more luminaires can be determined. The average maintained intensity at any point on the pavement can be obtained by multiplying the sum of the initial footcandle [lux], from the various contributing light sources, by the luminaire maintenance factor of 0.70.

Computer programs are available to calculate lighting intensity and other information such as uniformity. These programs can be used for most lighting configurations. Several figures have been developed for many typical layouts to aid the designer in determining location and type of luminaires.

- 8-01.6 (1) (a) CONTINUOUS LIGHTING.** The configuration, spacing and type of luminaires for continuous lighting depends on many factors, including the type of roadway, the adjacent roadway features, the roadway width, and the setback of the luminaires from the edge of the traveled way. [Figures 8-01.9 and 8-01.10](#) show types of luminaires and maximum spacing for staggered configurations and one sided configurations to provide the required intensity and uniformity. The staggered configuration is preferred when possible since it provides better uniformity. Other configurations are possible and can be considered.
- 8-01.6 (1) (b) BASIC LIGHTING.** Basic lighting of 30 ft. [9 m] mounting height uses 150-watt Type III medium distribution, semi-cutoff luminaires. Basic lighting of 45 ft. [13.5 m] mounting height normally uses 250-watt Type III medium distribution, semi-cutoff luminaires. In some cases to obtain required intensities on island noses or in intersections, the 400-watt Type III medium distribution, semi-cutoff luminaires are used. [Figures 8-01.18, 8-01.19, 8-01.20 and 8-01.21](#) provide information for the location and types of luminaires to provide average maintained intensities for typical layouts.

For intersections with raised islands, [Figures 8-01.4, 8-01.18 and 8-01.20](#) should be used in conjunction to determine locations and types of luminaires. It is important that the luminaire bracket arms are oriented at right angles to the projected edge of through lanes as shown in [Figure 8-01.18](#) to provide the proper light distribution.

- 8-01.6 (2) UTILIZATION CURVES.** Utilization curves provide a means of determining the average footcandle [lux] illumination over the pavement where lamp size, mounting height, width of pavement, and spacing between luminaires is known or assumed. Conversely, the desired spacing or any other unknown factor may be determined if the other factors are given. The utilization factor varies to some extent with various makes of luminaires: however, the curves shown on [Figures 8-01.12, 8-01.13, 8-01.14 and 8-01.15](#) are considered

average and are used for design purposes. These curves are for a luminaire mounting height of 30 ft. [9 m]. Correction factors as listed are used for other mounting heights. The utilization curves show how much light falls on the pavement, but does not show how the light is distributed. They must be used with the iso-footcandle [iso-lux] diagrams for the same luminaire to evaluate uniformity and the ratio of minimum intensity to average intensity.

8-01.6 (3) FORMULAS FOR COMPUTATIONS

$$\text{Avg. (fc or lux)} = \frac{\text{Lamp lumens} \times \text{Utiliz. Coef.} \times \text{Maint. Factor}}{\text{Spacing (ft. or m)} \times \text{width of Rd. (ft. or m)}}$$

$$\text{Spacing} = \frac{\text{Lamp lumens} \times \text{Utiliz. Coef.} \times \text{Maint. Factor}}{\text{Avg. (fc or lux)} \times \text{Width of travel way (ft. or m)}}$$

Where:

Avg. fc = average footcandles (lumens/ft²); avg lux = average lux (lumens/m²)

Lamp lumens. = Initial lamp lumen rating

Utiliz. Coef. = Coefficient of Utilization

Maint. Factor = Luminaire and Lamp Maintenance Factor

8-01.7 ELECTRICAL COMPONENTS

8-01.7 (1) VOLTAGE DROP AND WIRE SIZES. Voltage drop is an important factor in determining wire sizes. The voltage drop in any electrical circuit is directly dependent upon current and wire resistance. According to Ohm's Law the voltage drop in a line is equal to the current in amperes multiplied by the resistance of the line in ohms:

$$E = I \times R$$

Where:

E = voltage

I = Current (in amperes)

R = Resistance (in ohms)

Since the resistance of a wire conductor is inversely proportional to the cross-sectional area of the wire, increased voltage drops are developed as the wire diameters decrease.

The areas of wires in circular mils [mm²] and the resistance in ohms per 1000 ft. [1000 m] to be used in calculations are shown in [Table 8-01.1](#) of [Figure 8-01.11](#). The voltage drop in any line is calculated from the formula:

ENGLISH

$$\text{Volts drop} = \frac{\text{Distance (ft)} \times \text{Amperes} \times 25}{\text{circular mils}}$$

METRIC

$$\text{Volts drop} = \frac{\text{Distance (m)} \times \text{Amperes} \times 0.04125}{\text{mm}^2}$$

Transposing this formula, the required area in circular mils [mm²] can be computed:

ENGLISH

$$\text{Area in circular mils} = \frac{\text{Distance} \times \text{Amperes} \times 25}{\text{Permissible voltage drop}}$$

METRIC

$$\text{Area in mm}^2 = \frac{\text{Distance} \times \text{Amperes} \times 0.04125}{\text{Permissible voltage drop}}$$

With the constant wattage ballast, the permissible voltage drop is five percent of the system voltage. A factor of 0.95 should be applied to the system voltage to allow for line fluctuations. This results in an allowable drop of 23 volts for a 480 volt circuit, and 11 volts for a 240 volt circuit.

8-01.7 (1) (a) MAXIMUM WIRE SIZES. Maximum wire sizes for lighting branch circuits (cables between control station and light poles) are as follows:

- Standard Light Poles (30 and 45 ft. [9 & 13.5 m] mounting height) and Underpass Luminaires - #6 AWG [16 mm²] MAXIMUM
- High Mast Light Poles - #2 AWG [35 mm²] MAXIMUM

If circuit loading or voltage drop requires a larger wire size than the maximum then one or more of the following can be considered:

- Increase the system voltage from 240 volts to 480 volts.
- Split the circuits into additional branch circuits. This may require parallel cable conduits in some parts of the system.
- Locate the control station closer to the lighting system.
- Install additional control stations.

Availability and proximity of power sources and system voltages is considered in obtaining the best solution. Where alternate configurations can achieve the same results, a rough cost comparison is made to determine the most economical configuration.

Wire sizes larger than #0 AWG [70 mm²] are not recommended for power supply cables (cables between power supply and base-mounted control station) since larger wire sizes are difficult to handle in the control stations and power supplies. If a larger wire size is required, a terminal strip is provided in the control cabinet to reduce the wire size.

8-01.7 (1) (b) EXAMPLE TO DETERMINE NECESSARY WIRE CABLE SIZE

Given: Five 250-watt lamps on a 480 volt circuit at 1200, 1700, 3700, 4300 and 4600 ft. [350, 500, 1100, 1300 and 1400 m], respectively, from the control station.

There must be sufficient operating current to the first lamp to operate it as well as the next four lamps, etc.

Operating current is determined using 95 percent of the system voltage to allow for line fluctuations. In addition, the lamp wattage is increased by a factor of 1.3 to allow for ballast load. The formula for power is $P = V \times I$ and the formula for current is $I = P / V$.

$$(250 \text{ watts} \times 1.3) / (480 \text{ volts} \times 0.95) = 0.71 \text{ amps}$$

It is also necessary to add 5% to the wire length to allow for snaking.

ENGLISH

$$1200 \text{ ft} \times 1.05 \times 5 \text{ lamps} \times 0.71 \text{ amps} \times 25/23 \text{ (Permissible Drop)} = 4862 \text{ cir. mils to 1st lamp}$$

$$500 \text{ ft} \times 1.05 \times 4 \text{ lamps} \times 0.71 \times 25/23 = 1621 \text{ cir. mils to 2nd lamp}$$

$$2000 \text{ ft} \times 1.05 \times 3 \text{ lamps} \times 0.71 \times 25/23 = 4862 \text{ cir. mils to 3rd lamp}$$

$600 \text{ ft} \times 1.05 \times 2 \text{ lamps} \times 0.71 \times 25/23 = 972 \text{ cir. mils to 4th lamp}$

$300 \text{ ft} \times 1.05 \times 1 \text{ lamp} \times 0.71 \times 25/23 = 243 \text{ cir. mils to 5th lamp}$

Total Area = 12,560 cir. mils.

METRIC

$350 \text{ m} \times 1.05 \times 5 \text{ lamps} \times 0.71 \text{ amps} \times 0.04125/23 \text{ (Permissible Drop)} = 2.34 \text{ mm}^2 \text{ to 1st lamp}$

$150 \text{ m} \times 1.05 \times 4 \text{ lamps} \times 0.71 \times 0.04125/23 = 0.80 \text{ mm}^2 \text{ to 2nd lamp}$

$600 \text{ m} \times 1.05 \times 3 \text{ lamps} \times 0.71 \times 0.04125/23 = 2.41 \text{ mm}^2 \text{ to 3rd lamp}$

$200 \text{ m} \times 1.05 \times 2 \text{ lamps} \times 0.71 \times 0.04125/23 = 0.54 \text{ mm}^2 \text{ to 4th lamp}$

$100 \text{ m} \times 1.05 \times 1 \text{ lamp} \times 0.71 \times 0.04125/23 = 0.13 \text{ mm}^2 \text{ to 5th lamp}$

Total Area = 6.22 mm².

The wire size is that with the area next above, as shown in [Table 8-01.1](#) of [Figure 8-01.11](#) or #8 AWG [10 mm²] (The minimum size used in cable-conduit is #8 AWG [10 mm²]). When several circuits are carried from one control station, determine the wire size for each circuit separately. #10 AWG [6 mm²] pole and bracket cable is used in all installations regardless of the size of the conductor cable. To check the preceding result, use the basic formula:

Voltage Drop = Current x Resistance

To determine the current in amperes, use length of wires (2 x distance) x number of lamps x line amperes. [Table 8-01.1](#) of [Figure 8-01.11](#) shows the resistance of #8 AWG [10 mm²] wire in ohms/1000 ft = 0.78 [ohms/1000 m = 2.2].

Therefore:

ENGLISH

$2 \text{ wires} \times 1200 \text{ ft} \times 1.05 \times 5 \text{ lamps} \times 0.71 \times 0.78 \text{ ohms/1000 ft} = 6.98 \text{ volt drop to 1st lamp}$

$2 \text{ wires} \times 500 \text{ ft} \times 1.05 \times 4 \text{ lamps} \times 0.71 \times 0.78 \text{ ohms/1000 ft} = 2.33 \text{ volt drop to 2nd lamp}$

$2 \text{ wires} \times 2000 \text{ ft} \times 1.05 \times 3 \text{ lamps} \times 0.71 \times 0.78 \text{ ohms/1000 ft} = 6.98 \text{ volt drop to 3rd lamp}$

$2 \text{ wires} \times 600 \text{ ft} \times 1.05 \times 2 \text{ lamps} \times 0.71 \times 0.78 \text{ ohms/1000 ft} = 1.40 \text{ volt drop to 4th lamp}$

$2 \text{ wires} \times 300 \text{ ft} \times 1.05 \times 1 \text{ lamp} \times 0.71 \times 0.78 \text{ ohms/1000 ft} = 0.35 \text{ volt drop to 5th lamp}$

Total Drop = 18.03 volts and $18.03 \text{ volts}/(480 \text{ volts} \times .95) = 3.96\%$

METRIC

$2 \text{ wires} \times 350 \text{ m} \times 1.05 \times 5 \text{ lamps} \times 0.71 \times 2.2 \text{ ohms/1000 m} = 5.74 \text{ volt drop to 1st lamp}$

$2 \text{ wires} \times 150 \text{ m} \times 1.05 \times 4 \text{ lamps} \times 0.71 \times 2.2 \text{ ohms/1000 m} = 1.97 \text{ volt drop to 2nd lamp}$

$2 \text{ wires} \times 600 \text{ m} \times 1.05 \times 3 \text{ lamps} \times 0.71 \times 2.2 \text{ ohms/1000 m} = 5.90 \text{ volt drop to 3rd lamp}$

$2 \text{ wires} \times 200 \text{ m} \times 1.05 \times 2 \text{ lamps} \times 0.71 \times 2.2 \text{ ohms/1000 m} = 1.31 \text{ volt drop to 4th lamp}$

$2 \text{ wires} \times 100 \text{ m} \times 1.05 \times 1 \text{ lamp} \times 0.71 \times 2.2 \text{ ohms/1000 m} = 0.33 \text{ volt drop to 5th lamp}$

$$\text{Total Drop} = 15.25 \text{ volts and } 15.25 \text{ volts}/(480 \text{ volts} \times .95) = 3.34\%$$

Circuit loading due to line losses should also be calculated for the purpose of sizing circuit breakers. The formula for power, $P = I \times V$ is used. Total current on each segment and the voltage drop as calculated above is used:

ENGLISH

5 lamps x 0.71 amps x 6.98 volts = 25 watts consumed to the 1st lamp

4 lamps x 0.71 amps x 2.33 volts = 7 watts consumed to the 2nd lamp

3 lamps x 0.71 amps x 6.98 volts = 15 watts consumed to the 3rd lamp

2 lamps x 0.71 amps x 1.40 volts = 2 watts consumed to the 4th lamp

1 lamp x 0.71 amps x 0.35 volts = 0 watts consumed to the 5th lamp

Total line loss load = 49 watts.

METRIC

5 lamps x 0.71 amps x 5.74 volts = 21 watts consumed to the 1st lamp

4 lamps x 0.71 amps x 1.97 volts = 6 watts consumed to the 2nd lamp

3 lamps x 0.71 amps x 5.90 volts = 13 watts consumed to the 3rd lamp

2 lamps x 0.71 amps x 1.31 volts = 2 watts consumed to the 4th lamp.

1 lamp x 0.71 amps x 0.33 volts = 0 watts consumed to the 5th lamp

Total line loss load = 42 watts.

8-01.7 (2) CIRCUIT BREAKERS. Circuit breakers are protective devices for over-current conditions. When the current passing through the circuit breaker coils exceeds a predetermined amount, the magnetic field developed is sufficiently large in magnetomotive force to trip the contacts and open the faulty circuit. The amount of current required to operate the trip mechanism is referred to as the "trip rating". Proper protection of the circuit requires a breaker with the correct "tripping" current value. This value, "trip rating", can readily be computed by totaling the number of luminaires for each circuit breaker and thereby obtaining the total current being used in the circuit.

To prevent unnecessary tripping of the breaker during surges and in-rush currents, the total current is usually multiplied by a factor of 1.3. Using the previous example: 5 each - 250-watt luminaires require a normal operating current of $5 \times (0.71 \text{ ampere}) = 3.67$ amperes.

The line loss load in amperes is added as follows:

$$42 \text{ watts}/(480 \text{ volts} \times 0.95) + 3.6 \text{ amps} = 3.7 \text{ amps}$$

Then: Trip rating = $3.7 \text{ amps} \times (1.3) = 4.8 \text{ amps}$.

Conventional circuit breakers for lighting systems are used in the following trip ratings: 15, 20, 25, 30, 35, 40, 50, 70, 90 and 100 amperes. For the above example, a 15 amp breaker would be used.